CHAPTER 4

CLASSIFICATION OF SOIL

تتكون التربة من خليط من الحبيبات مختلفة الأبعاد بمقاسات الزلط والرمل والطمى , والثلاث مقاسات يحتمل أن يكون لهم تركيب معدنى واحد , وقد تتضمن التربة الطين ، وله تركيب معدنى مختلف ، وتركيبات الطين ومجموعات معادنه - كما سبق ان ذكرنا - متنوعة بدرجة كبيرة . وتعتمد الخواص الهندسية لخليط التربة على نسب ونسق مكوناتة .

ويعتبر التصنيف الخطوة الأولى التى تجرى لتحديد "مجموعة" تنتمى اليها التربة , وهذه المجموعات لها صفات هندسية متنبؤ بها . والواقع أنه لأعمال الإنشاء الصغيرة يكتفى بالتصنيف لتقدير خواص التربة الهندسية ويتم تصميم الأساسات و أعمال الحفر وخلافه بناء على ذلك . أما بالنسبة للأعمال الكبرى فيتم أولا تصنيف التربة - كما سيتضح فى هذا الباب - وثانيا تجرى التجارب لتحديد صفات التربة الميكانيكية مباشرة بالدقة اللازمة .

The purpose of soil classification is to arrange various types of soil into groups according to their engineering characteristics. A classification system is used to find the suitability (مدى مناسبة) of for construction of dams, highways, foundations, ..etc.

Soil is generally composed of a mix of several components. These components are described individually in the following section.

4.1 Soil Components

4.1.1 Boulder

A boulder is a rounded to angular, bulky, hard, rock particle or fragment. The average diameter may by more than 300 mm.

4.1.2 Cobble

A cobble has the same description as a boulder but with smaller average diameter of about 150-300 mm. Boulders and cobbles are very stable components, used for fills and for stabilizing slopes. Because of size and weight, their occurrence in natural deposits tends to improve the stability of foundations.

4.1.3 Gravel (G)

A gravel is a rounded to angular, bulky, rock particles or fragment. Its size is smaller than 60 mm and larger than 2 mm. Gravel can be divided into fine, medium and coarse.

4.1.4 Sand (S)

Same as gravel, but smaller in size. Sand is divided into coarse, medium and fine. Gravel and sand have similar engineering properties differing mainly in degree. They are easy to compact, little affected by moisture, and not subjected to frost action. Gravels are stable, resistant to erosion and piping more than sand. The well graded sands and gravels are generally less pervious and more stable than those which are poorly graded (uniformly graded). Irregularity of particles increases the stability slightly. Finer uniform sand approaches the characteristics of silt, i.e., decrease in permeability and reduction in stability with increasing moisture.

4.1.5 Silt (M)

The silt particle size is smaller than No. 200 sieve (# 0.075 mm). Silt is identified by its behavior. It is slightly or none plastic, regardless the moisture content. It exhibits little or no strength when air dried.

Silt is inherently unstable, particularly when moisture is increased, with a tendency to become quick when saturated. It is relatively impervious, difficult to compact, highly susceptible to frost heave, can be easily eroded and subject to piping and boiling. Bulky grains reduce compressibility. Flakey grains increase compressibility and produce "elastic" silt.

4.1.6 Clay (C)

Clay particles are finer than No. 200 sieve (0.075 mm). They are identified by their behavior. Clay can be made to exhibit plastic properties within a certain range of moisture, and exhibits considerable strength when air dried.

The distinguishing characteristic of clay is cohesion, or cohesive strength, which increases with the decrease of moisture content. The permeability of clay is low. It is difficult to compact when wet and impossible to drain by ordinary means. When compacted it is resistant to erosion and piping. It is not susceptible to frost heave.

Clay is subjected to expansion and shrinkage with change of moisture. The properties of clay are influenced not only by size and shape of particles, but also by their mineral composition. As mentioned before, clay structure and macro fabric also play important role in its engineering characteristics.

4.1.7 Organic matter

المود العضوية مصدر مشاكل هندسية أذا زادت نسبتها فى التربة لأنها تسبب زيادة انضغاط التربة تحت تأثير حمل المنشآت . هذه المواد يمكن أن تكون ناتج تحلل نباتات أو كائنات يحرية دقيقة .

تتواجد المواد العضوية فى بعض أراضى وسط الدلتا على هيئة طبقات على عمق ٣ الى ١٠ متر تقريبا وبسمك من سنتيمترات إلى ٤ متر او أكثر . وهى عبارة عن نباتات متحللة منذ آلاف السنين بلون أسود مختلطة بنسبة من الطين . ومن أمثلة المشاكل التى حدثت بسبب وجود هذه الطبقات هبوط وميل عمارات فى مدينة المنصورة وتصدع مدرسة فى قرية المعتمدية مركز المحلة الكبرى .

Organic matter can be in various sizes and different stages of decomposition. When present, even in moderate amounts, it increases the compressibility and reduces the stability of the fine grained components. It may decay causing voids, or by chemical alteration changes the properties of soil. Hence, organic soils are not desirable for engineering uses.

4.2 Particle size classification (M.I.T Classification)

In this system, soils are arranged according to the grain size. Terms such as gravel, sand, silt and clay are used to indicate grain size, and not classify the natural soil types, which are mixture of particles of different sizes and exhibit definite characteristics. It is preferable to use the term ‘silt size’ and ‘clay size ‘ rather than silt and clay.

أبسط أنظمة تصنيف التربة هو نظام معهد مساشوستس للتكنولوجيا (الأمريكى) . ويعتمد هذا النظام كلية على تدرج التربة . وقد وضعت حدود لمقاسات الأنواع الرئيسية للتربة . لتطبيق هذا النظام يطلق على التربة أسمٌ مركبٌ يعتمد على نسب مكونات التربة من الزلط ورمل وطمى وطين ، فيذكر المكون الأكثر وزنا حسب ما يتضح من منحنى التدرج ويليه المكون الاقل نسبة وهكذا. وتستخدم أدوات إضافة للربط بين المكونات وإيضاح نسبتها بعضها الى بعض . هذه الأدوات هى :

الأداة	نسبة المكون التالى فى التربة - %	مثال
و	٣٥ _ ٥٠	رمل وطمى
صفة	١٥ _ ٣٥	رمل طميى
بعض	٥ _ ١٥	رمل وبعض طمى
اثار	١ - ٥	رمل واثار طمى

واذا احتوت العينة على زلط كبير ومتوسط ورفيع بنسب متقاربة يكتفى بان يقال زلط متدرج , وكذلك اذا احتوت العينة على رمل حرش ومتوسط وناعم بنسب متقاربة يكتفى بان يقال رمل متدرج , وكذلك اذا احتوت العينة على طمى خشن ومتوسط وناعم بنسب متقاربة يكتفى بان يقال طمى .

There are various grain size classification, the M.I.T (Massachusetts institute of technology) system is widely used, Fig. 4.1.

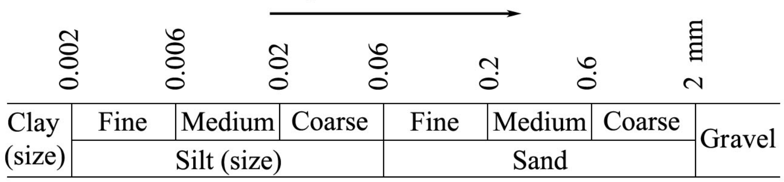


Fig. 4.1 M.I.T. particle size classification

4.3 Textural classification

يعطى تصنيف الـ M.I.T إنطباعا مباشرا غير واقعى عن الخواص الهندسية للتربة خاصة عندا احتوائها على تربة خشنة مع نسبة من الطمى والطين . فمثلا إذا تكونت تربة من ٤٠ % رمل , ٢٨ % طمى ٣٢ % طين ، فبنظام .M.I.T يطلق على هذه التربة اسم "رمل ونسبة من الطين ونسبة من الطمى" . ولكن الواقع أن حبيبات الطين الهائلة العدد ستغلف حبيبات الرمل والطمى وتصبح هى الروابط بينهم ولا يكون هناك أى اتصال بين الحبيبات الكبيرة من الطمى والرمل , مما يجعل سلوك التربة محكوما بخصائص الطين . ولذلك يكون اكثر واقعية إذا اطلق على هذه التربة إسم طين فقط . وقد وضع تقسيم الخشونة او "المثلث" بحيث يراعى ذلك. وتوجد انماط مختلفة من تقسيم المثلث اختير منهما المبين بالشكل .

Soils occurring in nature are composed of different percentages of sand, silt and clay particles. The classification of a composite soil based only on size distribution is called textural classification.

The best know classification system is the triangular classification, Fig.4.2. it is based on the concept that the percentages of clay and silt, which normally surround and link the coarse particles, are more significant to the soils behavior than its numeric value implies, Fig. 4.3. Such classification is more suitable for describing coarse grained soils rather than clay soils whose properties are less dependant on the particle size distribution.

To use the chart for given percentages of the three components forming soil, lines are drawn parallel to the three sides of the triangle, in the direction of the shown arrows. These lines will meet inside a division in which the name of the soil group is given. In case gravel size particles, the percentages of sand, silt and clay are readjusted such that their total become virtually 100% classification of the soil is firstly determined from the triangular chart, secondly, a term is added to the soil description in which the gravel content is presented.

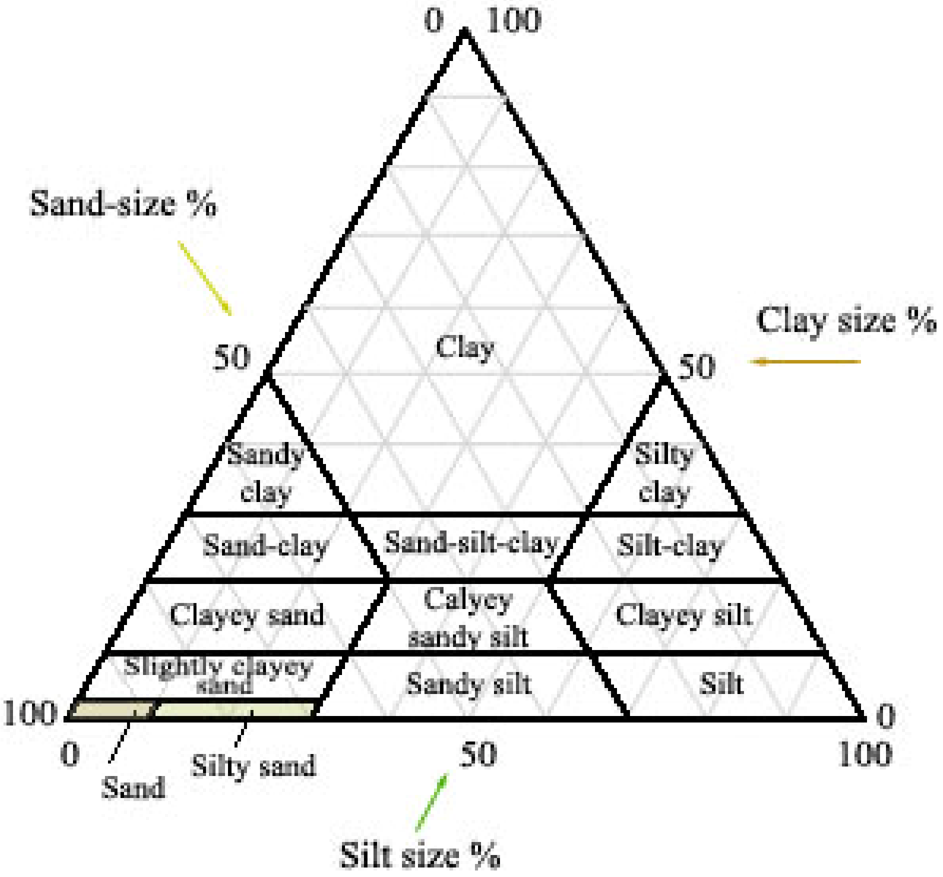
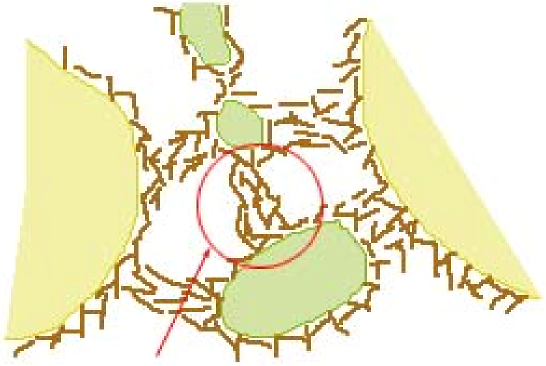


Fig. 4.2 Triangular soil classification



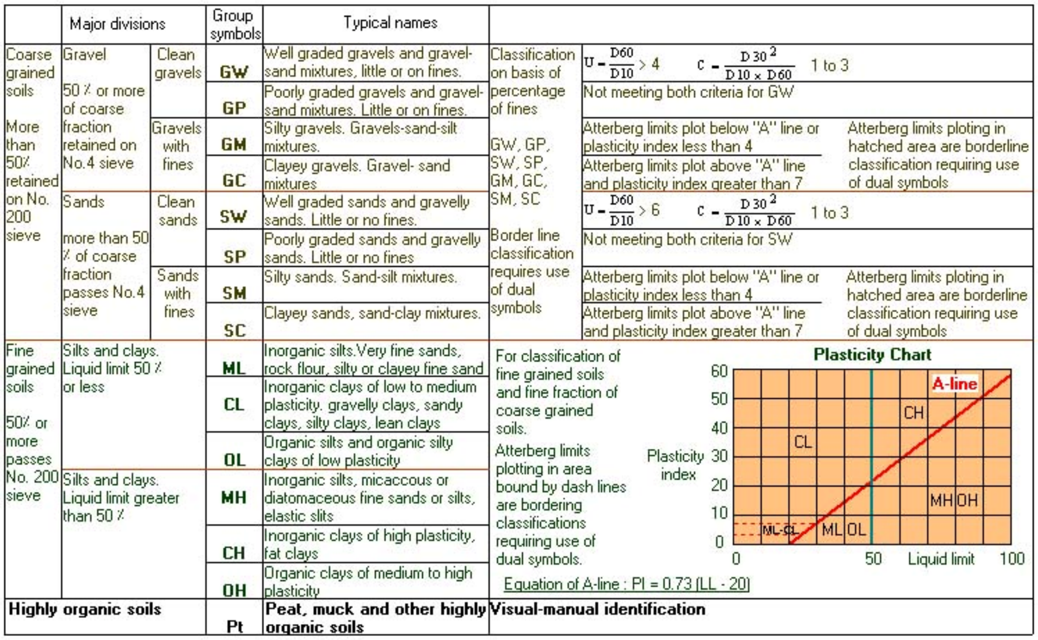
Clay link between larger particles

Fig. 4.3 Mixed soil structure

4.4 Unified soil classification

تصنيف التربة الموحد (unified) هو النظام الأكثر إنتشارا فى العالم وفيه يراعى فى التصنيف التدرج وخواص القوام . ففى تصنيف التربة الناعمة (الطميية والطينية) ، او الجزء الناعم من التربة فى الزلط والرمل , يستخدم النظام بيانى اللدونة الذى وضعه أ. كزاجراند فى الثلاثينيات . ويعطى هذا النظام حدودا لمجموعات التربة تتعين بالتجارب المعملية وبجانب ذلك فهو يعطى طرقا لتصنيف التربة حقليا . فبالنسبة الى التربة الخشنة يمكن تميز تدرجها بصريا على راحة اليد لكبر مقاس حبيباتها , ويميز الجزء الناعم فيها – اذا وجد – والتربة الناعمة بتجارب الاهتزاز والمقاومة للتربة الجافة والمقاومة للتشكل . ومع اهميتها كوسائل لتصنيف التربة حقليا فهى طرق بسيطة ويمكن اتقانها بالتدريب وتأكيد نتائجها مع التصنيف المستنتج من نتائج التجارب المعملية .

The Unified Soil Classification is based on both grain size distribution and plasticity properties of the soil, therefore , it is applicable to any use. Soils are broadly divided into three divisions, each division is subdivided into several groups as shown in Fig. 4.4.



	Major divisions		Group symbols	Typical names			
Coarse grained soils More than 50% retained on No. 200 sieve	Gravel 50 % or more of coarse fraction retained on No.4 sieve	Clean gravels	**GW**	Well graded gravels and gravel-sand mixtures, little or on fines.	Classification on basis of percentage of fines GW, GP, SW, SP, GM, GC, SM, SC Border line classification requires use of dual symbols	$U = \frac{D60}{D10} > 4$ $C = \frac{D30^2}{D10 \times D60}$ 1 to 3	
			GP	Poorly graded gravels and gravel-sand mixtures. Little or on fines.		Not meeting both criteria for GW	
		Gravels with fines	**GM**	Silty gravels. Gravels-sand-silt mixtures.		Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits ploting in hatched area are borderline classification requiring use of dual symbols
			GC	Clayey gravels. Gravel- sand mixtures		Atterberg limits plot above "A" line and plasticity index greater than 7	
	Sands more than 50 % of coarse fraction passes No.4 sieve	Clean sands	**SW**	Well graded sands and gravelly sands. Little or no fines.		$U = \frac{D60}{D10} > 6$ $C = \frac{D30^2}{D10 \times D60}$ 1 to 3	
			SP	Poorly graded sands and gravelly sands. Little or no fines		Not meeting both criteria for SW	
		Sands with fines	**SM**	Silty sands. Sand-silt mixtures.		Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits ploting in hatched area are borderline classification requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures.		Atterberg limits plot above "A" line and plasticity index greater than 7	
Fine grained soils 50% or more passes No. 200 sieve	Silts and clays. Liquid limit 50 % or less		**ML**	Inorganic silts.Very fine sands, rock flour, silty or clayey fine sand	For classification of fine grained soils and fine fraction of coarse grained soils. Atterberg limits plotting in area bound by dash lines are bordering classifications requiring use of dual symbols.	**Plasticity Chart** Equation of A-line : PI = 0.73 (LL - 20)	
			CL	Inorganic clays of low to medium plasticity. gravelly clays, sandy clays, silty clays, lean clays			
			OL	Organic silts and organic silty clays of low plasticity			
	Silts and clays. Liquid limit greater than 50 %		**MH**	Inorganic silts, micaccous or diatomaceous fine sands or silts, elastic slits			
			CH	Inorganic clays of high plasticity, fat clays			
			OH	Organic clays of medium to high plasticity			
Highly organic soils			**Pt**	**Peat, muck and other highly organic soils**	**Visual-manual identification**		

Fig. 4.4 The Unified Soil Classification System

4.4.1 Field identification procedure for fine grained soils

(a) Dilatancy : (Reaction to shaking)

After removing the particles larger than No.40 sieve size , prepare a pat of moisture soil with a volume of about 50 cm^3. add enough water, if necessary, to make the soil soft but not sticky. Place the pat in the opened palm of the hand and shake horizontally striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which becomes glossy. When the sample is squeezed between the fingers, the water and the gloss disappear from the surface, the pat stiffens, finally it cracks or crumbles. The rapidity of appearance of water during shaking, and its disappearance during squeezing, assist in identifying the character of the fines in a soil. Very fine clean sands give the quickest and most distinct reaction, whereas a plastic clay has no reaction. Inorganic silt, such as typical rock flour, shows a moderately quick reaction.

(b) Dry Strength : (Crushing characteristics)

After removing particles larger than No. 40 sieve size, mould a pat of the soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by an oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quality of the colloid fraction contained in the soil.

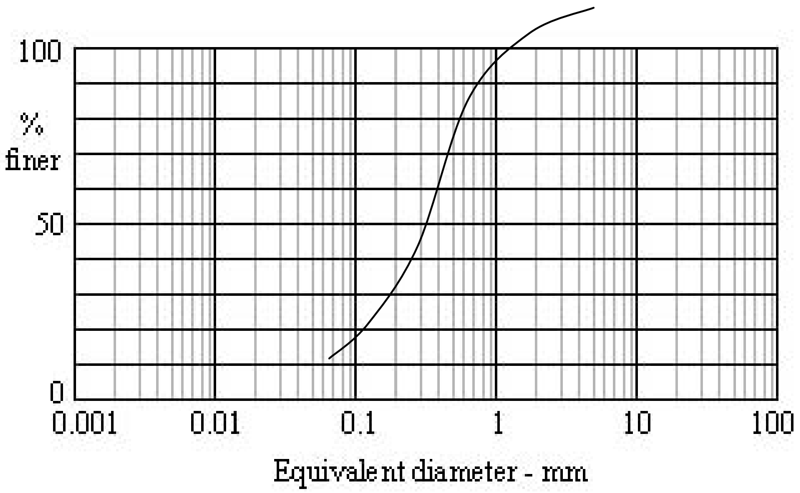
The dry strength increases with increase of plasticity. High dry strength is characteristic for clay of the (CH) group. A typical inorganic silt possesses only very slight dry strength. Silty fine sand and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty, whereas a typical silt has a smooth feel of flour.

(c) Toughness : (Consistency near plastic limit)

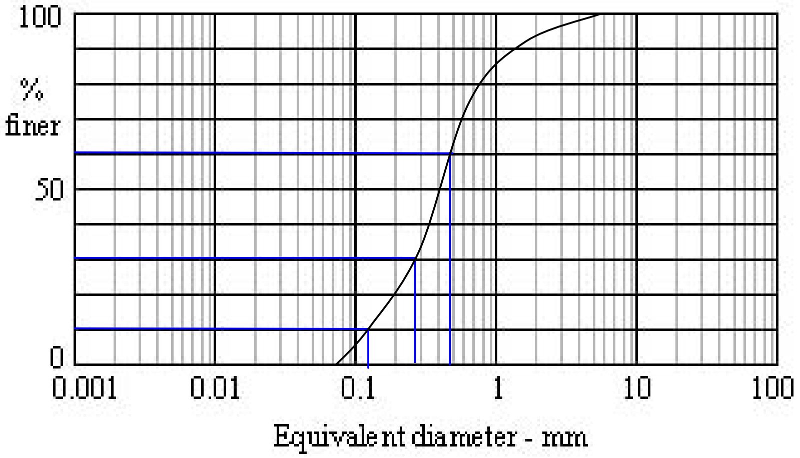
After removing particles larger than No. 40 sieve size, a specimen of Soil about 5 – 10 cm3 is remolded to the consistency of putty. If too dry, water must be added, and if sticky, the specimen should be spread out in a thin layer and allowed to loose some moisture by evaporation. Then the specimen is rolled out by the hand on a smooth surface or between the palms into a thread about 3 mm in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation, the moisture content is gradually reduced and the specimen stiffens, finally looses its plasticity and crumbles, the pieces could be lumped together and a slight kneading. Action continued until the lump crumbles. The tougher the thread near the plastic limit, and the stiffer the lump when it finally crumbles, the more is the called clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump the plastic limit indicates either inorganic clay of low plasticity, or material such as kaolin-type clays and organic clays which occur below the A-line. Highly organic clays have a very weak and spongy feel at the plastic limit.

4.5 Examples

(1) For the shown particle size distribution, find the effect diameter, uniformity coefficient and coefficient of curvature. Describe the soil according to the M.I.T., and the Unified classification systems.



Solution:



$$\text{From curve: } D10 = 0.14$$

$$D60 = 0.57$$

$$D30 = 0.28$$

$$\therefore \quad U = \frac{0.57}{0.14} = 4.1$$

$$\& \quad C = \frac{(0.28)^2}{0.14 \times 0.57} = 0.98$$

The sample does not include either clay or silt fraction. Distribution of sand and gravel is as follows:

Sand			Gravel		
Fine	Medium	Coarse	Fine	Medium	Coarse
18	45	27	10	-	-
90			10		

- Description according to M.I.T. system: Medium to coarse and fine sand, some gravel. (خشن وناعم هنا صفة للرمل الذى تصنيفه الرئيسى متوسط الخشونة)
- Description according to the Unified classification system: SP

(2) Results of a particle size distribution test give:

Gravel content: 6 %

Sand content: 68 %

Silt content: 10 %

Clay content: 16 %

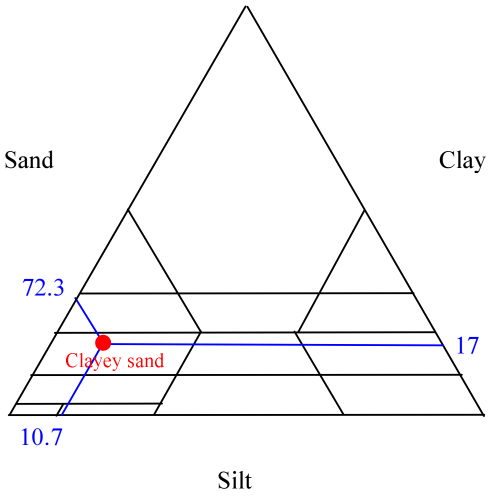
Classify the soil according to the textural (triangular) classification system.

Solution:

The sum of clay, silt and sand contents is : 68 + 10 + 16 = 94 %. To apply the textural (triangular) classification system, these contents are adjusted as follows:

Sand content = 68/0.94 = 72.3 %,
silt content = 10/0.94 = 10.7 %
Clay content = 16/0.94 = 17 %

The point corresponding to the adjusted contents is plotted as follows:



Adding the effect of gravel content, the soil is classified as: Clayey sand, some gravel.

(3) Given the results of sieve analysis and Atterberg limits, classify each soil according to the Unified classification system.

Soil	% pass. # 4	% pass. # 200	D10 mm	D30 mm	D60 mm	LL %	PL %
A	٩٨	١٦	0.045	0.13	0.32	48	20
B	٤٤	٣	0.16	1.2	4.85	-	-
C	٩٠	٨	0.1	0.32	0.9	36	26
D	[illegible]	[illegible]	-	-	-	73	26

Solution:

Soil	PI %	U	C	% retained on # 4	% pass. # 4 and retained on # 200	Group symbol
A	28	-	-	2	82	SC
B	-	30.0	1.26	56	41	GW
C	10	9	1.14	10	82	SW-SM
D	47	-	-	-	-	CH

Soil A :

1- % finer than sieve # 200 > 12 %, then soil is GM, GC, SM or SC.
2- > 50 % of the coarse fraction is finer than sieve # 4, then soil is S.
3- Determine PI.
4- From the plasticity chart, the fine fraction is C.
5- Group symbol is SC.

Soil B :

1- % finer than sieve # 200 < 5 %, then soil is GW, GP, SW or SP.
2- More than 50 % of the coarse fraction is retained on sieve # 4, then soil is G.
3- U > 4 and C = 1 to 3
4- Group symbol is GW.

Soil C :

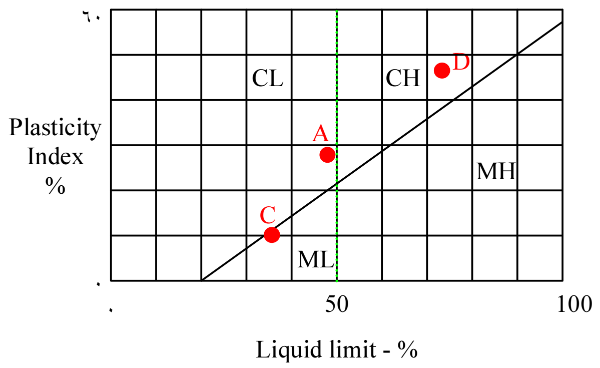
1- % finer than sieve # 200 = 5 to 12 %, then dual symbol will be used (e.g. SW-SC, .. .
2- More than 50 % of the coarse fraction is finer than sieve # 4, then soil is S.
3- U > 6 and C = 1 to 3
4- Soil is SW
5- Determine PI
6- From the plasticity chart the fine fraction is M
7- Group symbol is SW-SM.

Soil D :

1- % finer than sieve # 200 > 50 %, then soil is CH, CL, MH or ML

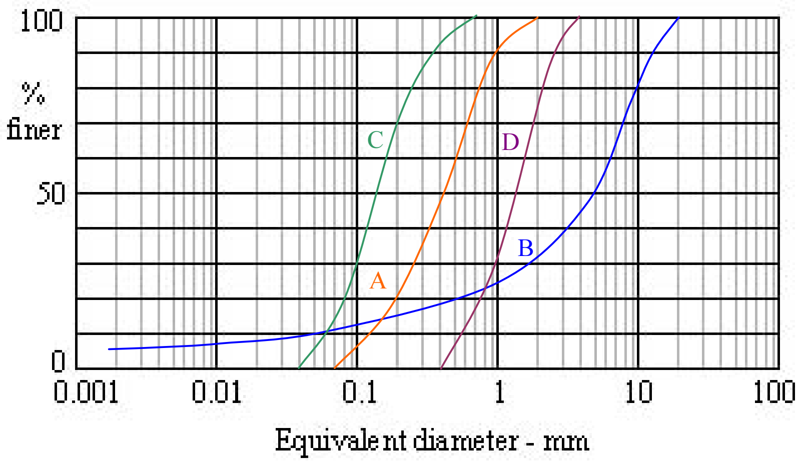
2- Determine PI

3- From the plasticity chart, the Group symbol is CH.



4.6 Problems

(1) The grading curves for four soils A, B, C and D are shown below. Classify these soils according to the M.I.T. classification system. Comment on the grading of soil A.



(2) Two soils A and B consist of the following:

Soil	Gravel	Sand	Silt	Clay
A	-	68	18	14
B	12	56	24	8

Classify each soil according to the textural (triangular) classification system.

(3) The data obtained from sieve analysis, liquid and plastic limit tests are given below. Classify each soil according to the unified classification system.

Soil	%pass . # 200	%pass . # 4	D10 mm	D30 mm	D60 mm	LL	PL
A	15	78	-	-	-	56	25
B	6	52	0.15	0.8	3.0	39	30
C	64	100	-	-	-	76	42
D	3	95	0.12	0.18	0.33	41	28
E	84	100	-	-	-	65	33
F	8	78	0.1	0.3	0.7	56	27

❑ ❑ ❑